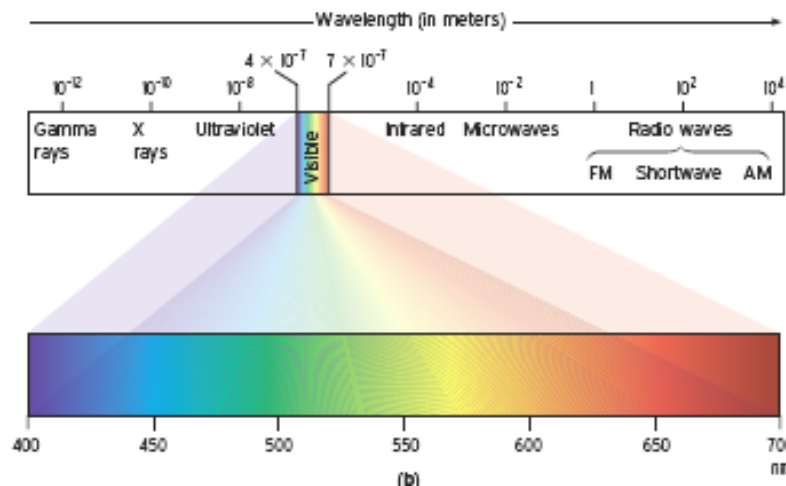
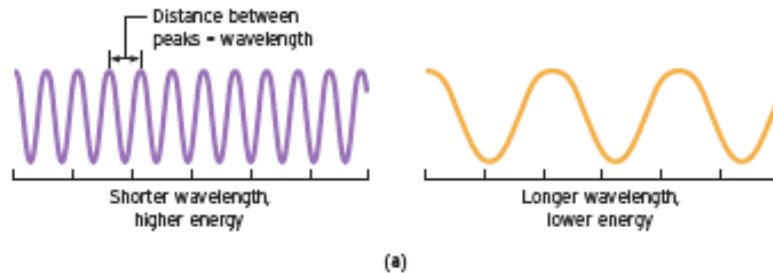


# **Color, Art, and Chemistry**

Dr. Sakya S. Sen  
CSIR-National Chemical Laboratory  
Pashan, Pune 411008

# Light: Electromagnetic Radiation

Light is a form of energy that travels through space like a wave and is characterized by its *wavelength*.

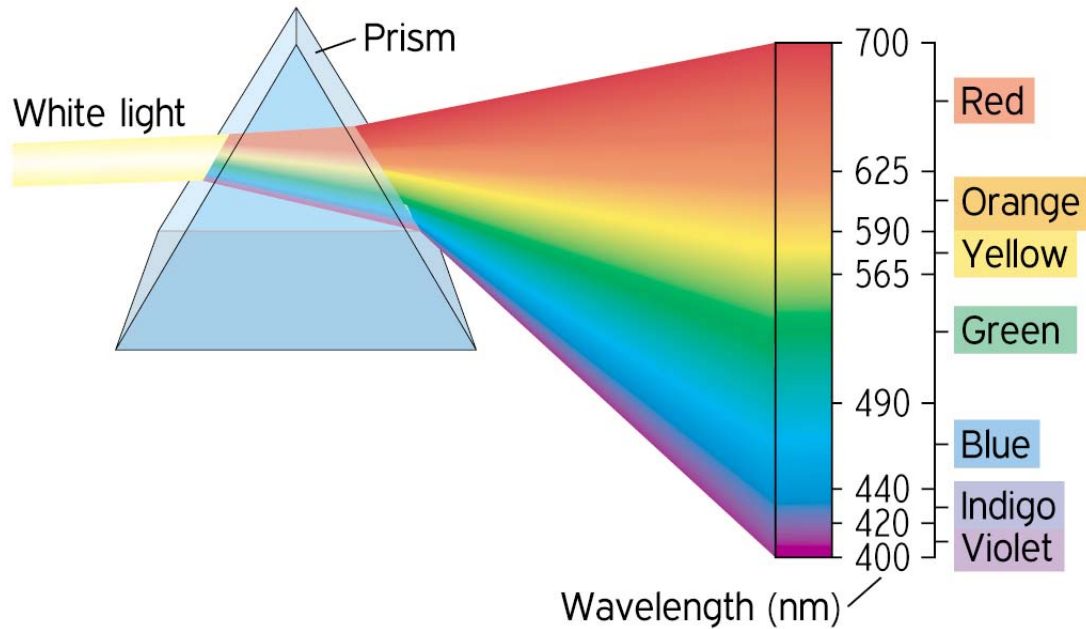


Only certain wavelengths of light can be detected by the human eye.

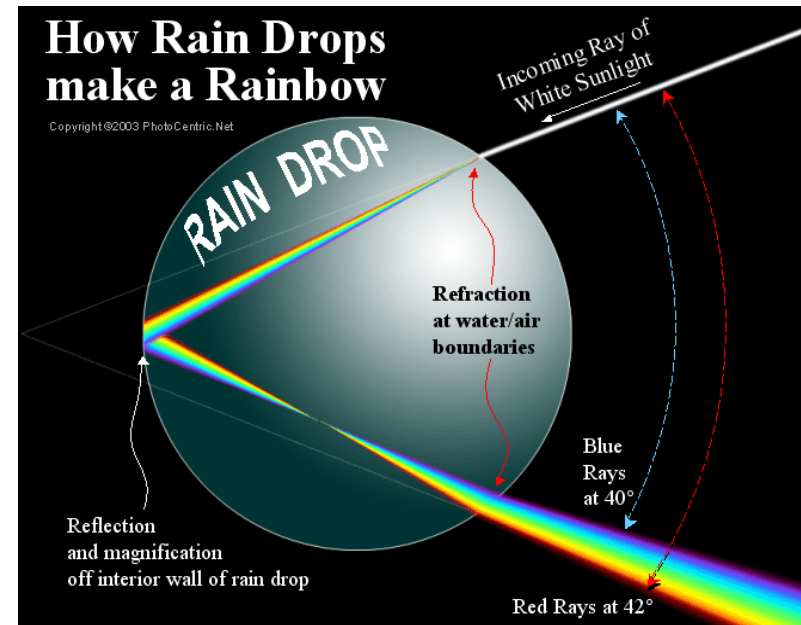
V I B G Y O R

# What is Color?

“White” light is actually composed of all colors in equal amounts.



# A natural Prism

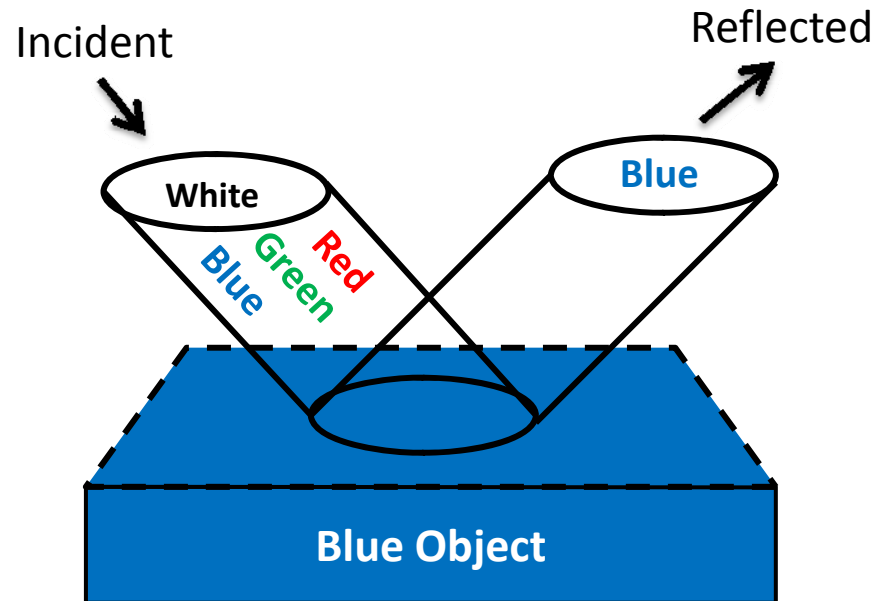


Two physical phenomena are at work within a rainbow: **refraction** and **reflection**.

This is the familiar prism effect wherein "white" sunlight is broken into a spectrum of different colors from red to blue-violet.

# The Color of Objects

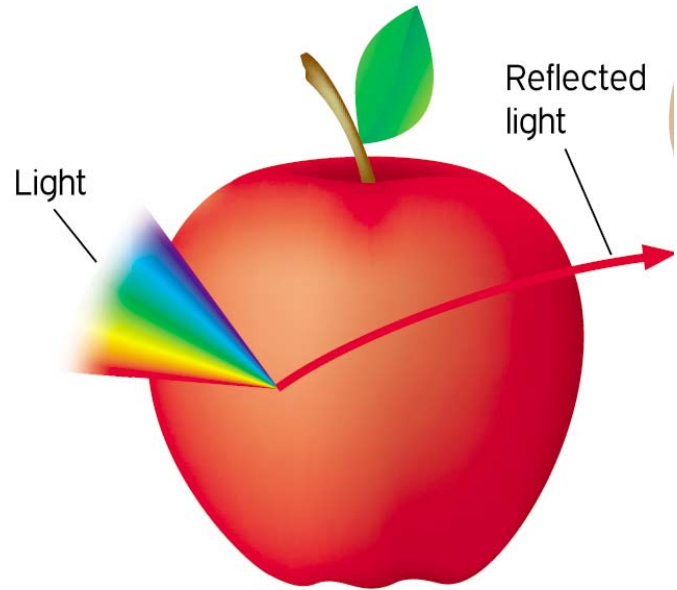
- If all wavelengths in sunlight are reflected, the object is white
- If all are absorbed, it is black



**If some of the visible wavelengths are absorbed and others reflected, the object is colored**

# Color Perception

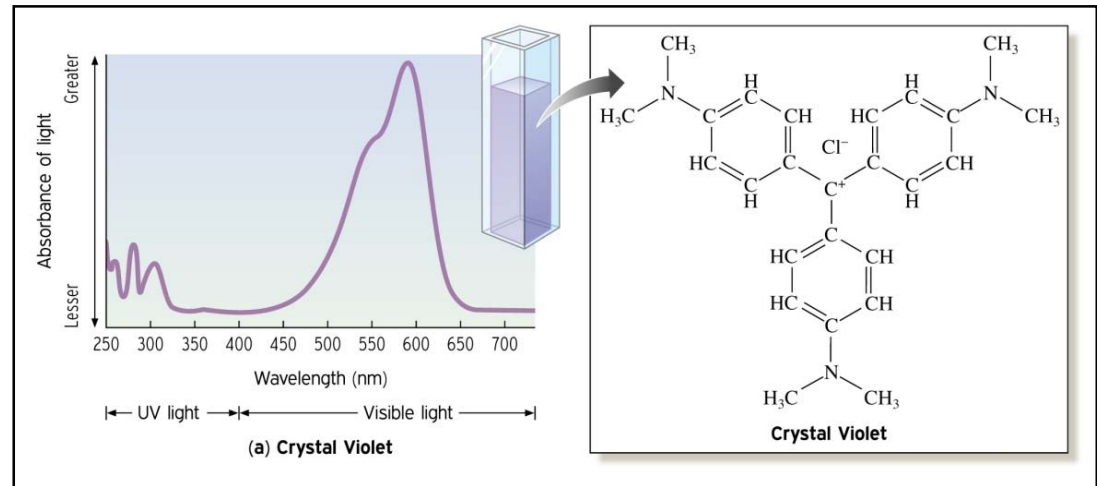
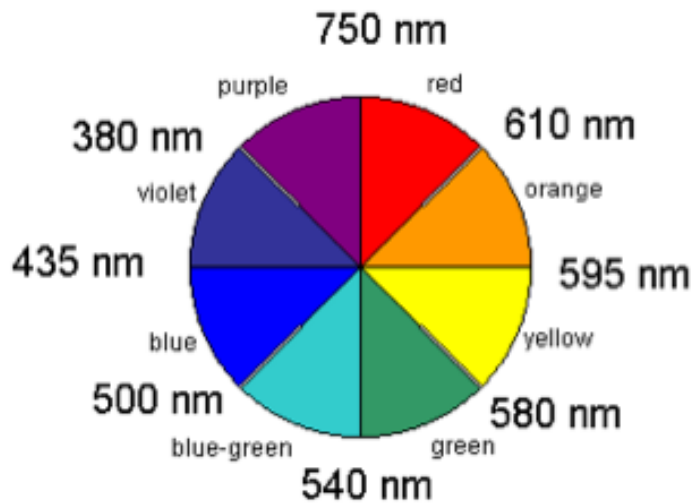
Why apple is red?



The apple has absorbed the other colors, and lets only the red light reflected.

# Complementary Color

Color Absorbed Determines the Color Observed



Color Wheel

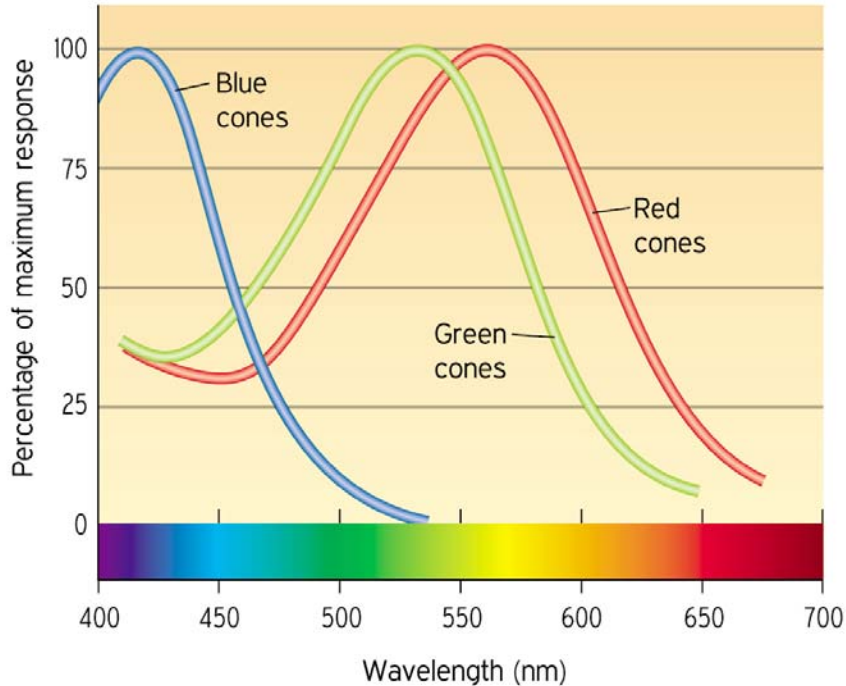
# Absorbance Measurement



UV-Visible Spectrophotometer



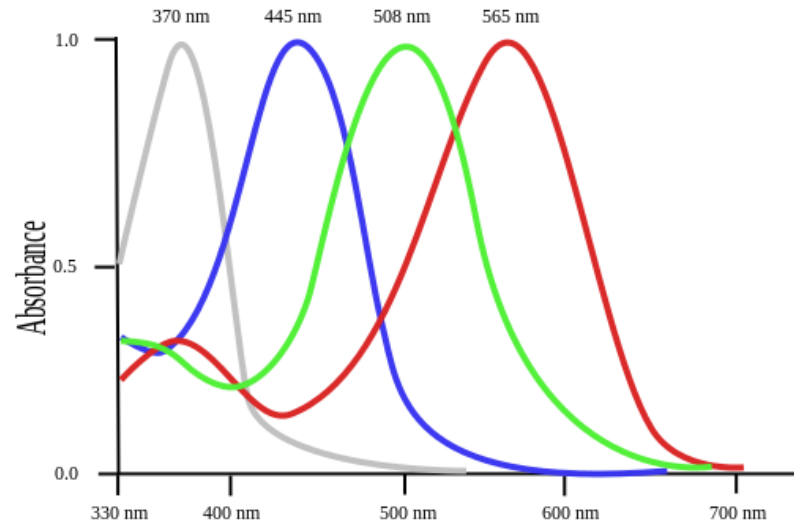
# Color Perception



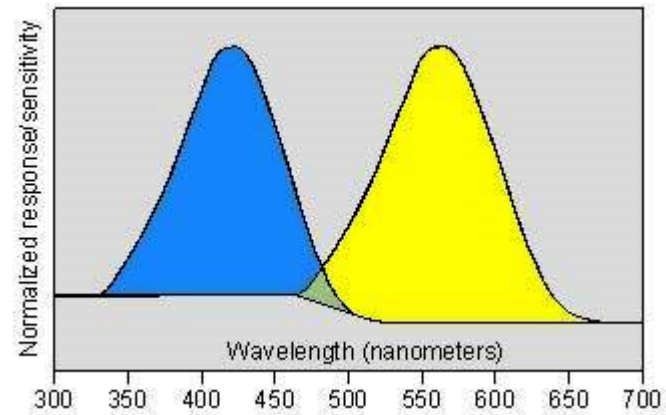
- There are three different kinds of human cone cells varying in their sensitivities to different colors of light: **blue**, **green**, and **red**.
- Sometimes called long, medium and short cones.
- Leads to trichromatic color vision (*Proposed by Young and Helmholtz*)

# Color Perception

Birds have four different kinds of cones (one in the UV).



Dogs have only two (Blue and yellow)

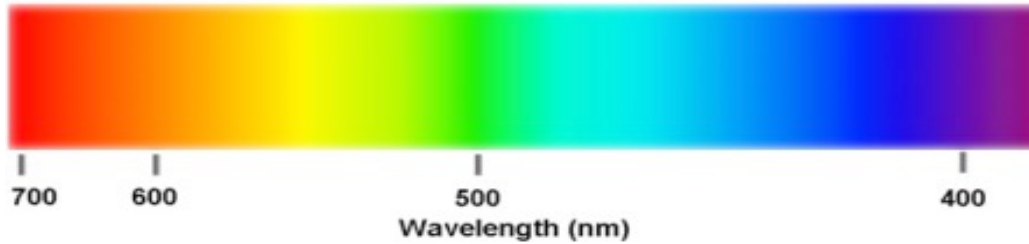


# Comparison of Dog, Human, and Bird's view

The Dog's View



The Human's View



The Bird's View



# Experiment on Dog's view



Fig. 1.2.3A

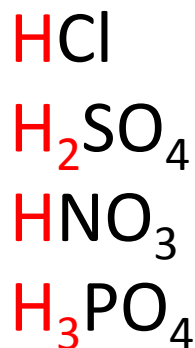


Fig. 1.2.3B

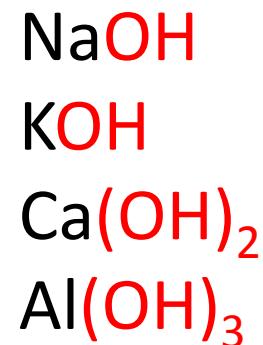
**In discrimination studies**, the dog is trained to indicate when he sees a circle that looks different from the other two. In this case he would pick the blue circle (Fig. 1.2.3A). Dogs can't distinguish between red and green, so in this trial the dog would not signal any difference because he can't see any (Fig. 1.2.3B). Photos courtesy of Gerald Jacobs, Professor of Psychology, University of California, Santa Barbara

# Acid, Base and pH in a nutshell

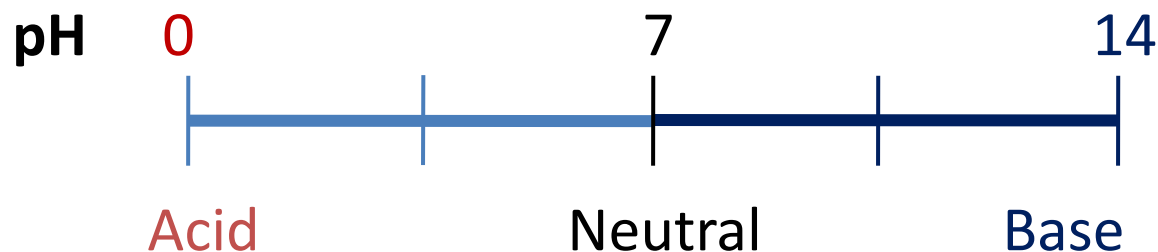
## Acids



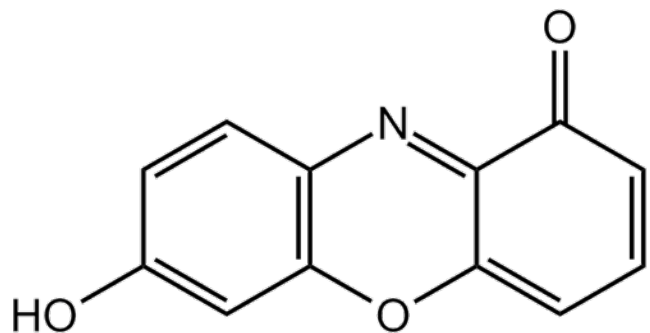
## Bases



**pH** is a measure of the concentration of  $\text{H}^+$  ions in a solution



# Litmus Test



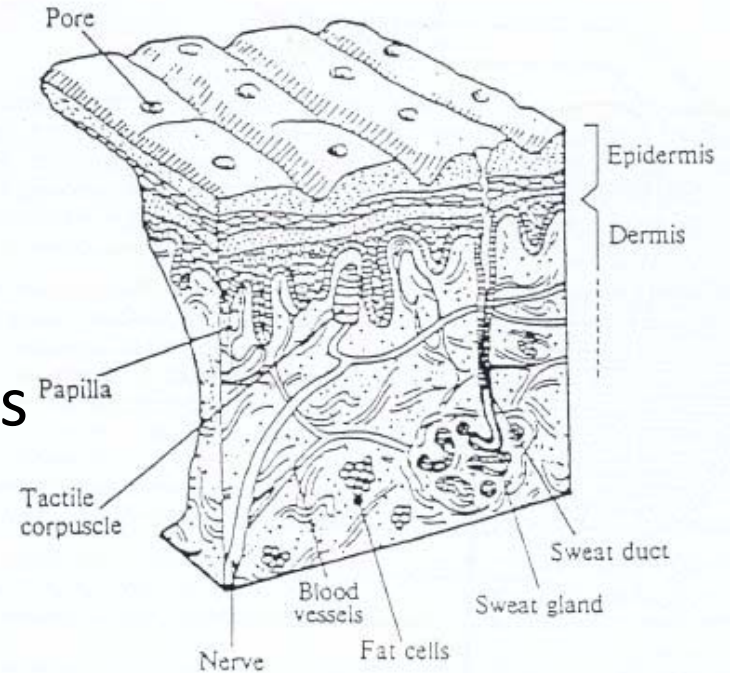
Acid Solution



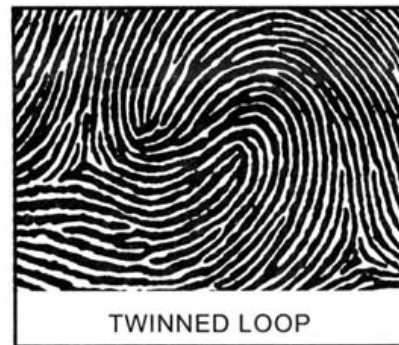
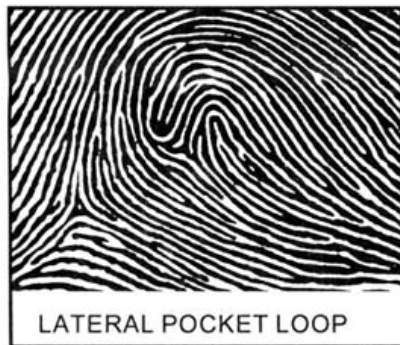
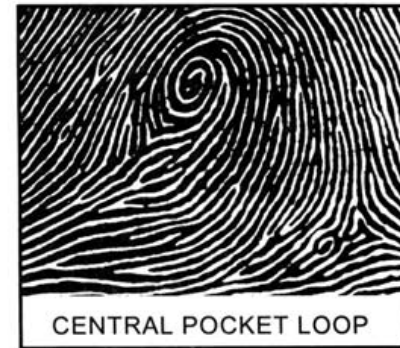
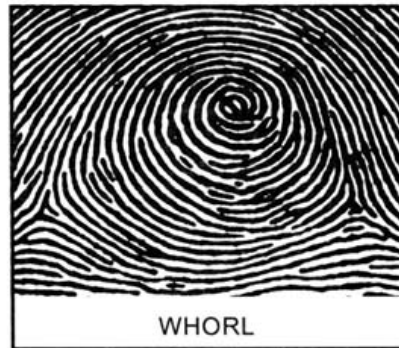
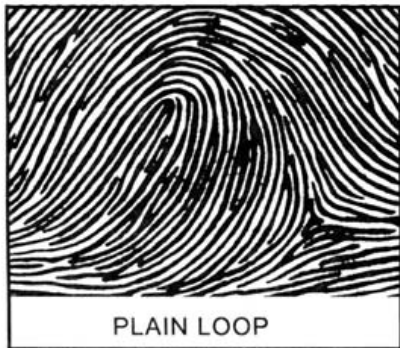
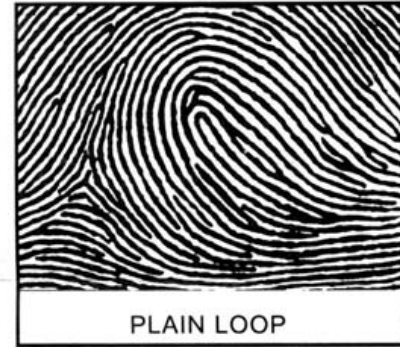
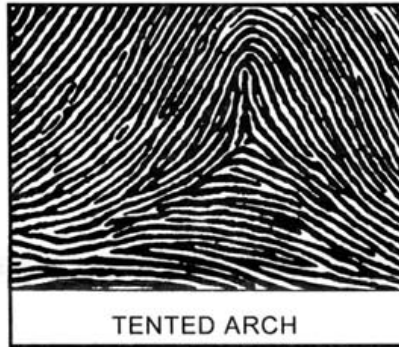
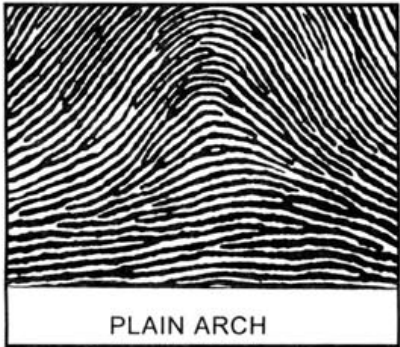
Basic Solution

# To Catch a Thief: Fingerprints

- The fingers of a person contain small ridges.
- The ridges form a pattern that is unique to each individual.
- Those ridges contain sweat pores from which are excreted perspiration, salts and oils.
- The oils that are left on a surface are known as latent fingerprints.



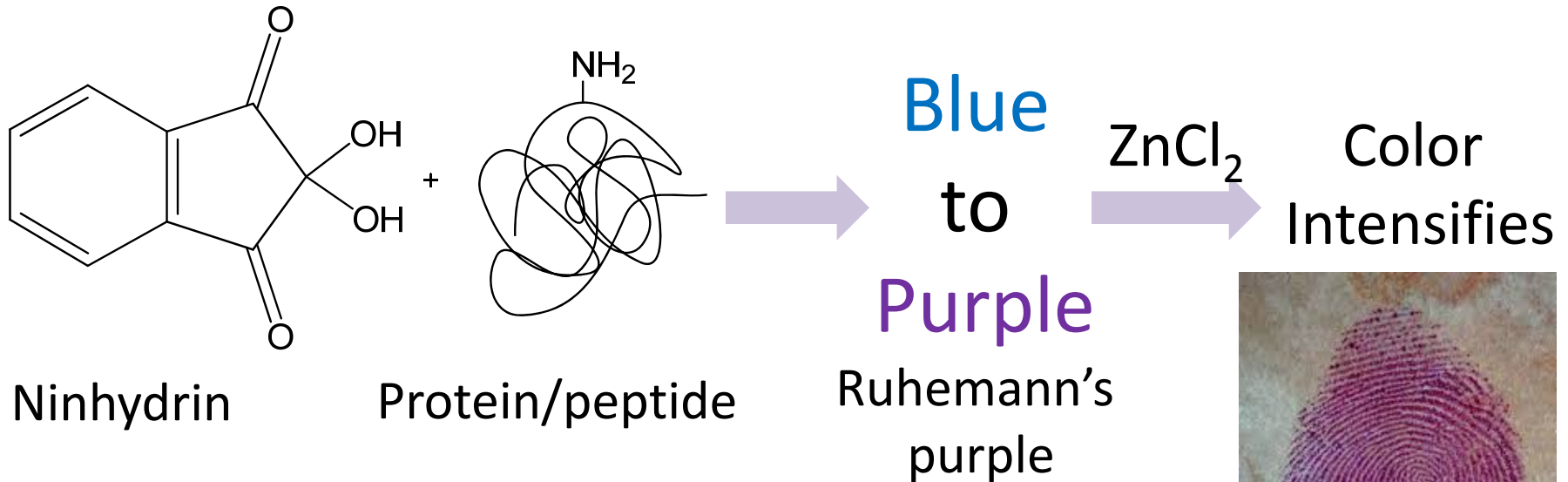
# Fingerprint Patterns





# Visualizing Fingerprints: Ninhydrin

1910, Siegfried Ruhemann discovered:

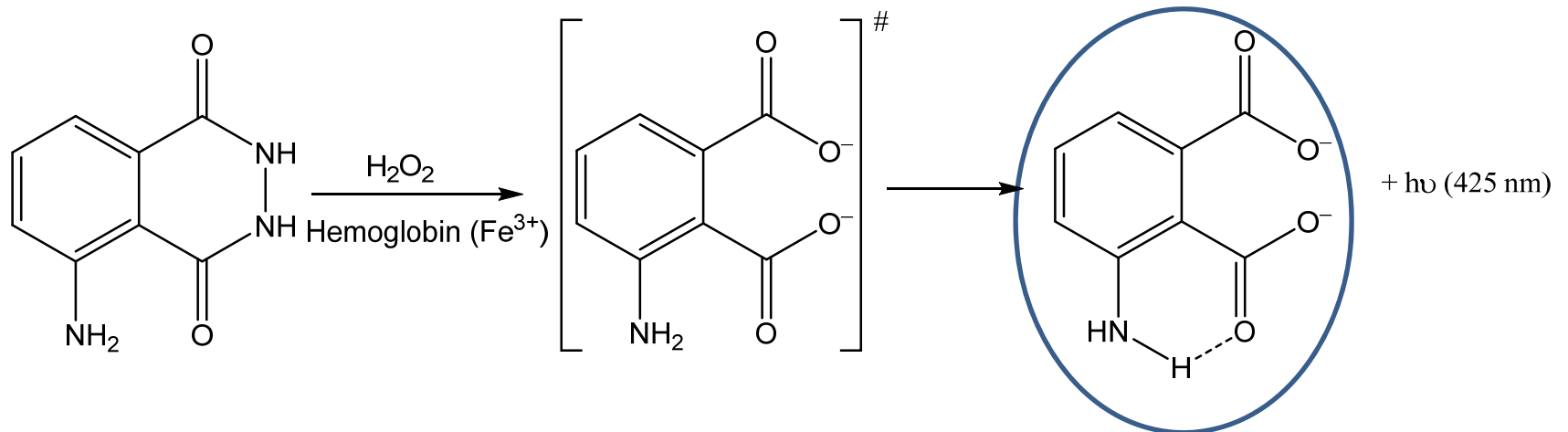


1954, Odén and von Hofsten suggested its use in criminal investigations:

# Indicators to Detect Blood in Crime Scene



Blood stains before  
and after luminol  
spray



# Ancient Art



Cave paintings from Altamira, Spain

Satyajit Ray refused to be a professional artist after seeing the picture at Kolkata Art Museum and decided to become a film director!!

# Paints

All paints have three types of components:

- Pigments
- Media
- Diluents

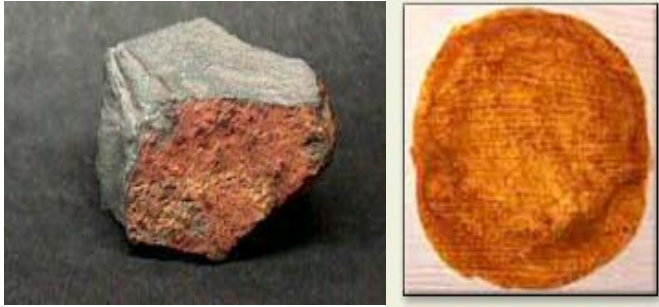


# Pigments

- Pigments consist of small particles of colored compounds.
- Are derived from finely ground naturally occurring minerals: rocks and ores.



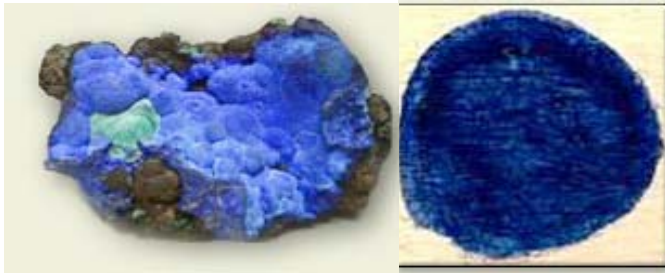
# Mineral-Based (*Inorganic*) Pigments



hematite ( $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ ):  
source of red, yellow, and  
brown ochre



cinnabar ( $\text{HgS}$ ) is a source of the  
red pigment vermilion



azurite ( $2 \text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ )



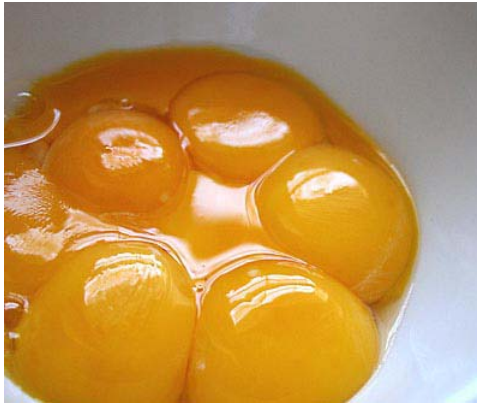
malachite;  $\text{Cu}_2\text{CO}_3(\text{OH})_2$



Orpiment

Van Gogh's mental illness and Monet's blindness  
were probably caused by orpiment!

# Media/Binder



- Media serves to suspend the pigments and bind them to the surface of the object painted.
- Examples are: beeswax, linseed oil, walnut oil, plaster, gum arabic and egg yolk.



# Diluents

Diluents such as water, turpentine, or mineral spirits allow the painter to thin the paint to the best consistency for the work.





# Blue Pigments



- Blue pigments like azurite and cuproriviate are rare
- Egyptians has tremendous attraction towards Lapis Lazuli



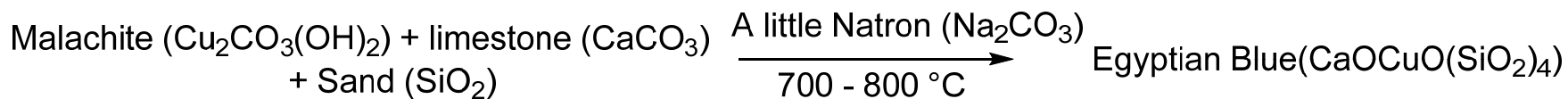
Beautiful jewelry is made from lapis lazuli

# Egyptian Blue [CaOCuO(SiO<sub>2</sub>)<sub>4</sub>]

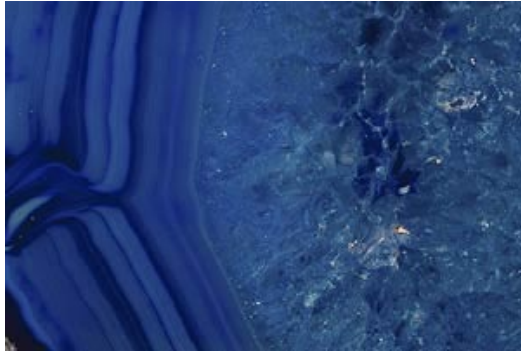


- It is one of the oldest man-made colors.
- Commonly found on wall paintings in Egypt, Mesopotamia and Rome.
- Composition: Calcium copper silicate
- Grinding sand, copper (malachite), limestone, and slight natron, and heating the mixture in a furnace gives glittering blue material

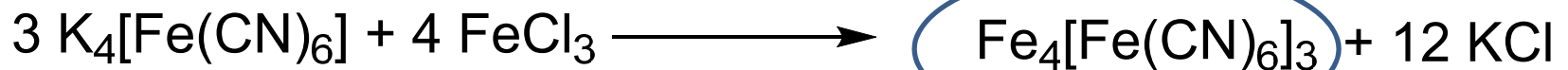
## Reaction

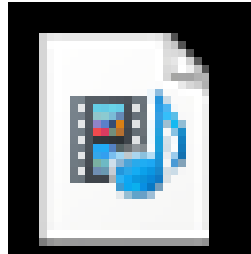


# Iron or Prussian Blue



- The iron blues are the first of the artificial pigments with a known history and an established date of first preparation.
- The color was made by the Berlin color maker Diesbach in or around 1704.





Suxvvdq#eoxh#vro1PRY1ps7

# Prussian Blue in medieval art



*The Great Wave off Kanagawa* by Hokusai, a famous artwork which makes extensive use of Prussian blue



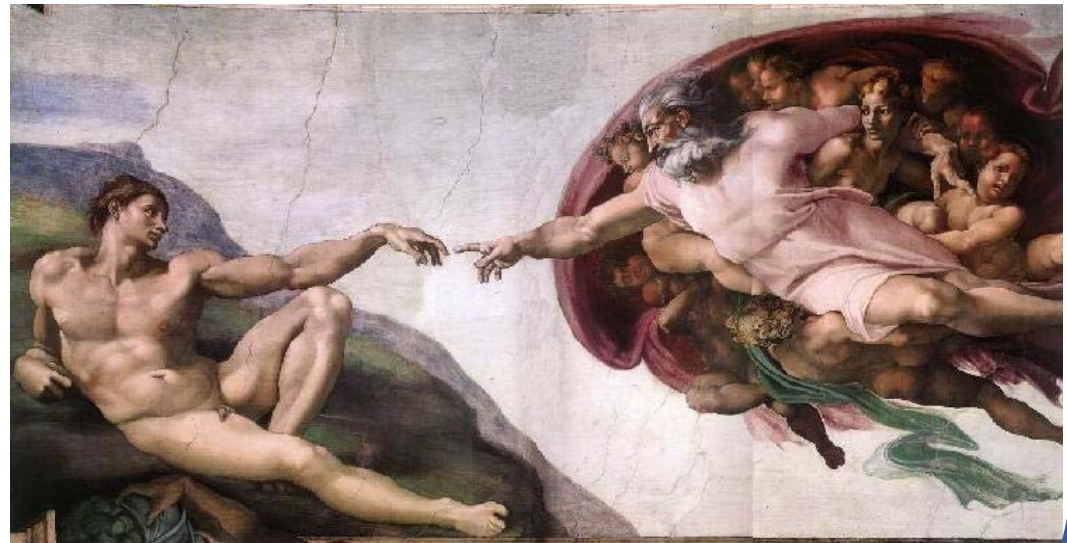
Vincent van Gogh's *Starry Night* uses Prussian blue pigments

# The Frescos

Michelangelo: Created the most influential works in Fresco in the western art history



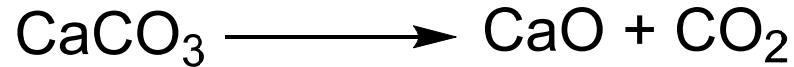
Ceiling of Sistine Chapel,  
Vatican City



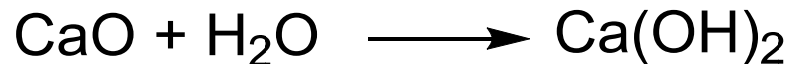
Creation of Adam

# Making The Frescos

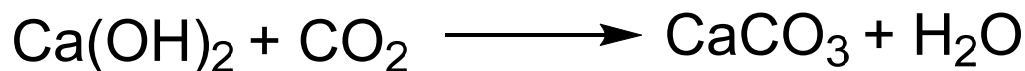
- Limestone or marble which is made up from calcium carbonate is heated in a lime kiln



- The quicklime is then "slaked" with water to produce lime,  $\text{Ca(OH)}_2$ , which is used to prepare the plaster.



- Prepare the mixture of a colored pigment and the yolk of an egg and water (egg tempera). Paint on the plaster.
- The egg temperas were absorbed into freshly spread wet plaster and remained vibrant as long as the paint survived
- As the plaster dries and ages, the calcium hydroxide reacts with  $\text{CO}_2$  in the air changing it from  $\text{Ca(OH)}_2$  to  $\text{CaCO}_3$ , which is the mineral that comprises limestone and marble.



# Egg Tempera



- Until the 15th century, egg yolk was used as the most common binder and medium for paints.
- Egg tempera is prepared by mixing egg yolks with a slurry of artist's pigment in water.
- Enough water is added to provide the proper consistency for painting.



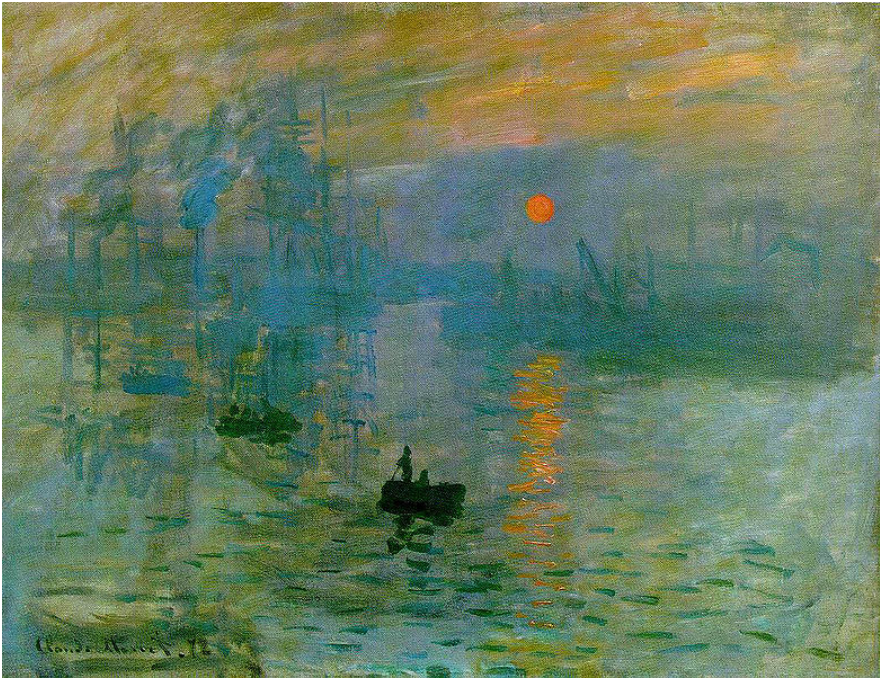
# Oil Painting

- By the 15th century, oil paints, using vegetable oils as the medium, replaced egg tempera as the most common paint.
- The oil most commonly used is linseed oil or turpentine oil which is obtained from the seed of the flax plant.
- The oil does not dry but rather is cross-linked where there are carbon-carbon double bonds in the oil.

# Difference between Egg Tempera and Oil Painting

- The Drying process is slow because cross-linking occurs under air oxidation
- However, it was soon discover that adding some metal oxides like ZnO or MnO<sub>2</sub> could also start the cross-linking process and speed up this hardening process

# Oil Paintings



Sunrise- An impression by Monet



Starry Nights by Van Gogh

# Art Conservation

- Great works of art are susceptible to effects of aging: atmospheric oxygen, temperature and humidity changes, air pollution and exposure to light
- Conservation involved cleaning the work, analyzing the work for damage, restoring the damaged areas and preserving the original
- Modern Analytical techniques are very routinely used: Infrared Reflectography, Laser Raman Spectroscopy, Autoradiography, Microscopic analysis etc

**Artists, Material Scientists, Spectroscopists work together**

# Restoration of Sistine Chappel

Pre-restoration



*Treated with solution containing:*

- Ammonium Bicarbonate
- Sodium Bicarbonate
- Desogen (Surfactant and antibacterial agent)
- Carboxymethylcellulose (thixotropic agent)

Post restoration





Practicing SCIENCE is a Fun, as well  
as a Challenge. Experience it.....

THANKS